What is claimed is:

1. A plasma arc torch comprising:

a cathode;

an electrode electrically connected to the cathode; and

a tip surrounding at least a portion of the electrode in spaced relationship therewith to define a gas passage, the gas passage being in fluid communication with a source of working gas for receiving working gas into the gas passage such that working gas within the gas passage swirls about the outer surface of the electrode, the tip having a central exit orifice in fluid communication with the gas passage;

the outer surface of the electrode being textured to promote turbulence of working gas flowing over the outer surface of the electrode as working gas swirls within the gas passage for enhancing convective cooling of the electrode.

2. A plasma arc torch as set forth in claim 1 wherein the textured outer surface of the electrode has dimples formed therein.

3. A plasma arc torch as set forth in claim 1 wherein the textured outer surface of the electrode comprises at least one groove formed therein, the at least one groove extending in a direction generally crosswise to the direction that working gas swirls within the gas passage about the outer surface of the electrode, said at least one groove at least partially extending axially within the outer surface of the electrode and being sized to turbulate the working gas flowing over the outer surface of the electrode.

4. A plasma arc torch as set forth in claim 3 wherein the textured outer surface of the electrode has a plurality of axially extending grooves formed therein, the axially extending

grooves being in generally parallel spaced relationship with each other about the outer surface of the electrode.

5. A plasma arc torch as set forth in claim 4 wherein the grooves extend axially within the outer surface of the electrode along substantially the entire length of said at least a portion of the electrode surrounded by the tip to define the gas passage therebetween.

6. A plasma arc torch as set forth in claim 3 wherein the at least one groove spirals downward within the outer surface of the electrode in a direction counter to the direction that working gas swirls about the outer surface of the electrode within the gas passage.

7. A plasma arc torch as set forth in claim 6 wherein the pitch of said at least one spiral groove is approximately equal to or less than the pitch of the working gas swirling within the gas passage.

8. A plasma arc torch as set forth in claim 3 wherein the working gas swirling within the gas passage defines a hydrodynamic boundary layer adjacent the outer surface of the electrode, the boundary layer including a turbulent outer layer, the at least one groove being sized to turbulate working gas in the hydrodynamic boundary layer generally adjacent the outer surface of the electrode to increase turbulent flow in the boundary layer for enhancing convective cooling of the electrode.

9. A plasma arc torch as set forth in claim 1 wherein the standard gas flow velocity of working gas flowing within the gas passage is at least about 140 ft/sec.

10. A plasma arc torch as set forth in claim 9 wherein the standard gas flow velocity of working gas flowing within the gas passage is at least about 160 ft/sec.

11. A plasma arc torch as set forth in claim 10 wherein the standard gas flow velocity of the working gas flowing within the gas passage is at least about 190 ft/sec.

12. A plasma arc torch as set forth in claim 1 wherein the spacing between the textured outer surface of the electrode and an inner surface of the tip defines a cross-sectional area of the gas passage therebetween, the electrode and tip being sized relative to each other such that the cross-sectional area of the gas passage corresponds to a predetermined current level at which the torch is operated.

13. A plasma arc torch as set forth in claim 12 wherein the cross-sectional area of the gas passage is sized such that the standard gas flow velocity of working gas flowing within the gas passage is at least about 140 ft/sec. when the torch is operated at said predetermined current level.

14. A plasma arc torch as set forth in claim 13 wherein the predetermined current level at which the torch is operated is the range of about 40 amps to about 80 amps.

15. A plasma arc torch as set forth in claim 13 wherein the cross-sectional area of the gas passage is decreased as the current level at which the torch is operated is decreased.

16. A plasma arc torch comprising:

a cathode;

an electrode electrically connected to the cathode; and

a tip surrounding a portion of the electrode in spaced relationship therewith to define a primary gas passage, the primary gas passage being in fluid communication with a source of primary working gas for receiving primary working gas into the gas passage such that the primary working gas flows over an inner surface of the tip in the gas passage, the tip having a central exit orifice in fluid communication with the gas passage;

the inner surface of the tip being textured to promote turbulence of the working gas flowing through the gas passage over the inner surface of the tip for enhancing convective cooling of the tip.

17. A plasma arc torch as set forth in claim 16 wherein the textured inner surface of the tip has dimples formed therein.

18. A plasma arc torch as set forth in claim 16 wherein the textured inner surface of the tip has axially extending grooves formed therein.

19. A plasma arc torch as set forth in claim 16 wherein the textured inner surface of the tip has a generally spiral groove formed therein.

20. A plasma arc torch as set forth in claim 19 wherein working gas flows through the gas passage in a generally spiral flow direction about the electrode, the spiral groove in the inner surface of the tip spiraling in a direction counter to the spiral flow direction of the working gas through the gas passage.

21. A plasma arc torch comprising:

a cathode;

an electrode electrically connected to the cathode;

a tip surrounding a portion of the electrode in spaced relationship therewith to define a primary gas passage, the primary gas passage being in fluid communication with a source of primary working gas for receiving primary working gas into the gas passage, the tip having a central exit orifice in fluid communication with the gas passage; and

a shield cap surrounding the tip in spaced relationship with an outer surface of the tip to define a secondary gas passage for directing gas through the torch over the outer surface of the tip, the shield cap having at least one opening therein for exhausting gas in the secondary gas passage from the torch;

the outer surface of the tip being textured to promote turbulence of the gas flowing through the secondary gas passage over the outer surface of the tip for enhancing convective cooling of the tip.

22. A plasma arc torch as set forth in claim 21 wherein the textured outer surface of the tip has dimples formed therein.

23. A plasma arc torch as set forth in claim 21 wherein the textured outer surface of the tip has at least one groove formed therein.

24. A plasma arc torch as set forth in claim 23 wherein the at least one groove formed in the outer surface of the tip has a generally crosswise orientation relative to the flow direction of the gas flowing through the secondary gas passage.

25. A plasma arc torch as set forth in claim 24 where the groove is spiraled.

26. A plasma arc torch as set forth in claim 24 wherein the gas flows substantially axially through the secondary gas passage, the at least one groove comprising a plurality of

grooves formed in the textured outer surface of the tip extending generally circumferentially about the tip at intervals along the tip.

27. A plasma arc torch comprising:

a cathode;

an electrode electrically connected to the cathode;

a tip surrounding a portion of the electrode in spaced relationship therewith to define a primary gas passage, the primary gas passage being in fluid communication with a source of primary working gas for receiving primary working gas into the gas passage, the tip having a central exit orifice in fluid communication with the gas passage; and

a shield cap surrounding the tip in spaced relationship therewith to define a secondary gas passage for directing gas through the torch over an inner surface of the shield cap, the shield cap having at least one opening therein for exhausting gas in the secondary gas passage from the torch;

the inner surface of the shield cap being textured to promote turbulence of the gas flowing through the secondary gas passage over the inner surface of the shield cap for enhancing convective cooling of the shield cap.

28. A plasma arc torch as set forth in claim 27 wherein the textured inner surface of the shield cap has dimples formed therein.

29. A plasma arc torch as set forth in claim 27 wherein the textured inner surface of the shield cap has at least one groove formed therein.

30. A plasma arc torch as set forth in claim 29 wherein the at least one groove formed in the inner surface of the shield cap has a generally crosswise orientation relative to the gas flowing through the secondary gas passage.

31. A plasma arc torch as set forth in claim 30 where the at least one groove is spiraled.

32. A plasma arc torch as set forth in claim 30 wherein the gas flows substantially axially through the secondary gas passage, the at least one groove comprising a plurality of grooves formed in the textured inner surface of the shield cap extending generally circumferentially about the shield cap at intervals along the shield cap.

33. An electrode for use in a plasma arc torch of the type having a cathode, a gas passage defined at least in part by the electrode and a tip surrounding the electrode in spaced relationship therewith and working gas flowing through the gas passage in a generally swirling direction about an outer surface of the electrode, the electrode comprising:

an upper end adapted for electrical connection to the cathode;

a lower end face having a recess therein;

an insert in the recess of the lower end face, the insert being constructed of an emissive material; and

a longitudinal portion intermediate the upper end and the lower end face of the electrode for defining at least in part the gas passage through which working gas flows in a generally swirling direction about the electrode, the outer surface of said longitudinal portion of the electrode being textured to promote turbulence of the working gas swirling within the gas passage over the outer surface of the longitudinal portion of the electrode.

34. An electrode as set forth in claim 33 wherein the upper end of the electrode is configured for quick connect/disconnect connection with the cathode.

35. An electrode as set forth in claim 34 wherein the upper end of the electrode is configured for a threadless quick connect/disconnect connection with the cathode.

36. An electrode as set forth in claim 35 wherein the upper end of the electrode has a detent extending generally radially therefrom for threadless interconnection with the cathode of the plasma torch to inhibit axial movement of the electrode out of the torch.

37. An electrode as set forth in claim 33 wherein the textured outer surface of said longitudinal portion of the electrode has dimples formed therein.

38. An electrode as set forth in claim 33 wherein the textured outer surface of said longitudinal portion of the electrode comprises at least one groove formed therein, the at least one groove extending in a direction generally crosswise to the direction that working gas swirls within the gas passage about the outer surface of the electrode, said at least one groove at least partially extending axially within the outer surface of the electrode and being sized to turbulate the working gas flowing over the outer surface of the electrode.

39. An electrode as set forth in claim 38 wherein the textured outer surface of the electrode has a plurality of axially extending grooves formed therein, the axially extending grooves being in generally parallel spaced relationship with each other about the outer surface of said longitudinal portion of the electrode.

40. An electrode as set forth in claim 39 wherein said plurality of grooves extend axially within the outer surface of the electrode along substantially the entire length of said longitudinal portion of the electrode.

41. An electrode as set forth in claim 38 wherein the at least one groove spirals within the outer surface of the electrode toward the lower end face of the electrode in a direction counter to the direction that working gas swirls about the outer surface of the electrode within the gas passage.

42. An electrode as set forth in claim 41 wherein the pitch of said at least one spiral groove is approximately equal to or less than the pitch of the working gas swirling downward within the gas passage.

43. An electrode as set forth in claim 38 wherein the working gas swirling within the gas passage defines a hydrodynamic boundary layer adjacent the outer surface of the electrode, the boundary layer including a turbulent outer layer, the at least one groove in the electrode being sized to turbulate working gas in the hydrodynamic boundary layer generally adjacent the outer surface of the electrode to increase turbulent flow in the boundary layer for enhancing convective cooling of the electrode.

44. An electrode as set forth in claim 33 wherein the cross-sectional area of said longitudinal portion of the electrode corresponds to a predetermined current level at which the torch is operable.

45. A torch tip for use in a plasma arc torch of the type having a cathode, a primary gas passage defined at least in part by an electrode electrically connected to the cathode and

the tip surrounding the electrode in spaced relationship therewith and working gas flowing through the primary gas passage, the torch tip comprising:

a lower end having a central exit orifice in fluid communication with the primary gas passage for exhausting working gas from the primary gas passage; and

an inner surface exposed for fluid contact by working gas in the primary gas passage;

the inner surface of the tip being textured to promote turbulence of the gas flowing through the primary gas passage over the inner surface of the tip for enhancing convective cooling of the tip.

46. A torch tip as set forth in claim 45 wherein the textured inner surface of the tip has dimples formed therein.

47. A torch tip as set forth in claim 45 wherein the textured inner surface of the tip has axially extending grooves formed therein.

48. A torch tip as set forth in claim 45 wherein the textured inner surface of the tip has a generally spiral groove formed therein.

49. A torch tip as set forth in claim 48 wherein the spiral groove formed in the inner surface of the tip is oriented in a direction generally crosswise to the direction that gas flows within the primary gas passage.

50. A torch tip for use in a plasma arc torch of the type having a cathode, a primary gas passage defined at least in part by an electrode electrically connected to the cathode and the tip surrounding the electrode in spaced relationship therewith and working gas flowing through the primary gas passage, and a shield cap surrounding at least a portion of the tip in

spaced relationship therewith to define a secondary gas passage through which working gas flows, the torch tip comprising:

a lower end having a central exit orifice in fluid communication with the primary gas passage for exhausting working gas from the primary gas passage; and

an outer surface exposed for fluid contact by working gas in the secondary gas passage;

the outer surface of the tip being textured to promote turbulence of the gas flowing through the secondary gas passage over the outer surface of the tip for enhancing convective cooling of the tip.

51. A torch tip as set forth in claim 50 wherein the textured outer surface of the tip has dimples formed therein.

52. A torch tip as set forth in claim 50 wherein the textured outer surface of the tip has axially extending grooves formed therein.

53. A torch tip as set forth in claim 50 wherein the textured outer surface of the tip has a generally spiral groove formed therein.

54. A torch tip as set forth in claim 53 wherein the spiral groove formed in the outer surface of the tip is oriented in a direction generally crosswise to the direction that gas flows within the secondary gas passage.

55. A shield cap for use in a plasma arc torch of the type having a cathode, a primary gas passage defined at least in part by an electrode electrically connected to the cathode and a tip surrounding the electrode in spaced relationship therewith and working gas flowing

through the primary gas passage, the shield cap surrounding at least a portion of the tip in spaced relationship therewith to define a secondary gas passage through which working gas flows, the shield cap comprising:

a lower end having at least one exhaust orifice in fluid communication with the secondary gas passage for exhausting working gas from the secondary gas passage; and

an inner surface exposed for fluid contact by working gas in the secondary gas passage;

the inner surface of the shield cap being textured to promote turbulence of the gas flowing through the secondary gas passage over the inner surface of the shield cap for enhancing convective cooling of the shield cap.

56. A shield cap as set forth in claim 55 wherein the textured inner surface of the shield cap has dimples formed therein.

57. A shield cap as set forth in claim 55 wherein the textured inner surface of the shield cap has axially extending grooves formed therein.

58. A shield cap as set forth in claim 55 wherein the textured inner surface of the shield cap has a generally spiral groove formed therein.

59. A shield cap as set forth in claim 58 wherein the spiral groove formed in the inner surface of the shield cap is oriented in a direction generally crosswise to the direction that gas flows within the secondary gas passage.

60. A series of electrodes for use in a plasma arc torch of the type having a cathode, an electrode electrically connected to the cathode, a tip surrounding at least a portion of the

electrode in spaced relationship therewith to define a gas passage, the gas passage being in fluid communication with a source of working gas for receiving working gas into the gas passage such that the working gas flows within the gas passage in a generally swirling direction about an outer surface of the electrode in the gas passage, the tip having a central exit orifice in fluid communication with the gas passage, said series of electrodes comprising:

at least two interchangeable electrodes, each electrode corresponding to a different current level at which the torch is operable, the outer surface of each electrode being textured to promote turbulence of the working gas flowing over the outer surface of the electrode as the working gas swirls about the electrode, the cross-sectional area of the textured outer surface of each electrode increasing as the current level at which the torch can be operated decreases to thereby decrease the cross-sectional area of the gas passage as the current level decreases.

61. A series of electrodes as set forth in claim 60 wherein the torch is further of type wherein the standard volumetric flow rate of gas through the torch is decreased as the current level at which the torch is operated decreases, the cross-sectional area of the textured outer surface of each electrode being sized to maintain a standard gas flow velocity in the gas passage of at least about 140 ft/sec as the current level at which the torch is operated decreases.

62. A series of tips for use in a plasma arc torch of the type having a cathode, an electrode electrically connected to the cathode, a tip surrounding at least a portion of the electrode in spaced relationship therewith to define a gas passage, the gas passage being in fluid communication with a source of working gas for receiving working gas into the gas passage such that the working gas flows within the gas passage in a generally swirling direction about an outer surface of the electrode, the electrode outer surface being textured to

promote turbulence of the working gas flowing over the outer surface of the electrode as working gas swirls about the electrode, the tip having a central exit orifice in fluid communication with the gas passage, said torch being operable at different current levels, said series of tips comprising:

at least two interchangeable tips, each tip corresponding to a different current level at which the torch is operable, the central exit orifice of the tips substantially decreasing as the current level at which the torch can be operated decreases, each tip having an inner surface defining an inner cross-sectional area of the tip, the inner cross-sectional area of the tips substantially increasing as the current level at which the torch can be operated decreases.

63. A series of tips as set forth in claim 62 wherein the torch is further of type wherein the standard volumetric flow rate of gas through the torch is decreased as the current level at which the torch is operated decreases, the inner cross-sectional area of each tip being sized to maintain a standard gas flow velocity in the gas passage of at least about 140 ft/sec as the current level at which the torch is operated decreases.

64. A series of electrode and tip sets for use in a plasma arc torch of the type having a cathode, an electrode electrically connected to the cathode, a tip surrounding at least a portion of the electrode in spaced relationship therewith to define a gas passage, the gas passage being in fluid communication with a source of working gas for receiving working gas into the gas passage such that the working gas flows over an outer surface of the electrode in the gas passage in a generally swirling direction about the electrode, the tip having a central exit orifice in fluid communication with the gas passage, said torch being operable at different current levels, said series of electrode and tip sets comprising:

a plurality of electrode and tip sets, each set corresponding to a different current level at which the torch is operable, each set comprising an electrode having a textured outer surface to promote turbulence of the working gas flowing over the outer surface of the electrode as the working gas swirls about the electrode, and a tip, whereby the size of the central exit orifice of the tip decreases for each set as the current level at which the torch is operable decreases, the electrode and tip of each set being sized relative to each other such that the cross-sectional area of the gas passage defined therebetween decreases for each set as the current level at which the torch is operable decreases.

65. A series of electrode and tip sets as set forth in claim 64 wherein the torch is further of type wherein the standard volumetric flow rate of gas through the torch is decreased as the current level at which the torch is operated decreases, the electrode and tip of each set being sized relative to each other to maintain a standard gas flow velocity in the gas passage of at least about 140 ft/sec as the current level at which the torch is operated decreases.

66. A method of improving the useful life of an electrode used in a plasma arc torch, the plasma arc torch comprising a cathode, an electrode electrically connected to the cathode and a tip surrounding a portion of the electrode in spaced relationship therewith to define a gas passage, the tip having a central exit orifice in fluid communication with the gas passage, the method comprising:

directing working gas through the gas passage for exhaust from the torch through the central exit orifice of the tip, the working gas swirling within the gas passage about the electrode to flow over an outer surface of the electrode as it is directed through the gas passage to define a hydrodynamic boundary layer generally adjacent the outer surface of the electrode, the boundary layer including a turbulent outer layer; and

turbulating the gas in the hydrodynamic boundary layer generally adjacent the outer surface of the electrode as gas is directed through the gas passage to increase turbulent flow in the boundary layer for enhancing convective cooling of the electrode thereby to improve the useful life of the electrode.

67. A method as set forth in claim 61 wherein the step of directing working gas through the gas passage comprises directing working gas through the gas passage at a standard flow velocity of at least about 140 ft/sec.

68. A method as set forth in claim 67 wherein the step of directing working gas through the gas passage comprises directing working gas through the gas passage at a standard flow velocity of at least about 160 ft/sec.

69. A method as set forth in claim 68 wherein the step of directing working gas through the gas passage comprises directing working gas through the gas passage at a standard flow velocity of at least about 190 ft/sec.

70. A method as set forth in claim 66 further comprising the step of decreasing the cross-sectional area of the gas passage as the current level at which the torch is operated is decreased.

71. A method as set forth in claim 66 wherein the step of turbulating the gas in the hydrodynamic boundary layer generally adjacent the outer surface of the electrode comprises directing the working gas swirling within the gas passage to flow over a textured outer surface of the electrode to promote turbulence of working gas generally adjacent the outer surface of the electrode as working gas swirls within the gas passage about the electrode.

72. A method of improving the useful life of a torch tip used in a plasma arc torch, the plasma arc torch comprising a cathode, an electrode electrically connected to the cathode, a torch tip surrounding a portion of the electrode in spaced relationship therewith to define a primary gas passage, the torch tip having a central exit orifice in fluid communication with the gas passage, and a shield cap surrounding the tip in spaced relationship therewith to define a secondary gas passage for directing working gas through the torch, the shield cap having at least one opening therein for exhausting gas in the secondary gas passage from the torch, the method comprising:

directing working gas through the secondary gas passage for exhaust from the torch through the at least one opening of the shield cap, the working gas flowing over an outer surface of the torch tip as it is directed through the secondary gas passage to define a hydrodynamic boundary layer adjacent the outer surface of the torch tip, the boundary layer including a turbulent outer layer; and

turbulating the gas in the hydrodynamic boundary layer adjacent the outer surface of the torch tip as gas is directed through the secondary gas passage to increase turbulent flow in the boundary layer for enhancing convective cooling of the torch tip thereby to improve the useful life of the torch tip.

73. A method of improving the useful life of a shield cap used in a plasma arc torch, the plasma arc torch comprising a cathode, an electrode electrically connected to the cathode, a torch tip surrounding a portion of the electrode in spaced relationship therewith to define a primary gas passage, the torch tip having a central exit orifice in fluid communication with the gas passage, and a shield cap surrounding the tip in spaced relationship therewith to define a secondary gas passage for directing working gas through the torch, the shield cap

having at least one opening therein for exhausting gas in the secondary gas passage from the torch, the method comprising:

directing working gas through the secondary gas passage for exhaust from the torch through the at least one opening of the shield cap, the working gas flowing over an inner surface of the shield cap as it is directed through the secondary gas passage to define a hydrodynamic boundary layer adjacent the inner surface of the shield cap, the boundary layer including a turbulent outer layer; and

turbulating the gas in the hydrodynamic boundary layer adjacent the inner surface of the shield cap as gas is directed through the secondary gas passage to increase turbulent flow in the boundary layer for enhancing convective cooling of the shield cap thereby to improve the useful life of the shield cap.

74. A method of improving the useful life of an electrode or tip of a plasma arc torch, the torch comprising a cathode, an electrode electrically connected to the cathode, and a tip surrounding a portion of the electrode in spaced relationship therewith to define an annular gas passage, the tip having a central exit orifice in fluid communication with the gas passage, the method comprising:

texturing the surface of at least one of the electrode and tip to promote turbulence of working gas flowing within the gas passage over the textured surface of said at least one of the electrode and tip;

changing the level of electrical current supplied to the electrode, and

modifying one or more of the following parameters in response to the change in current: (1) the standard volumetric gas flow rate through said annular gas passage, and (2) the dimensions of the annular gas passage.

75. A method as set forth in claim 74 wherein the dimensions of the annular gas passage are changed by at least one of the following: (1) increasing an outside dimension of the electrode and (2) decreasing an inside dimension of the tip.